

Power Supply System for Remote Site Application

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TABLE OF CONTENTS

ABSTRACT	IV
RÉSUMÉ	V
INTRODUCTION	1
DESCRIPTION	1
POWER-PAC	3
Design	4
Wiring details	6
Battery compartment	6
Control panel compartment	7
TELESCOPIC SOLAR PANEL AND WIND TURBINE STAND	9
Construction	11
Assembly instructions	12
Adjustment of the solar panel bed	13
WATER GENERATOR	14
Assembly	15
WIND TURBINE	16
GROUNDING	16
COSTS	17
DISCUSSION	18
WATER GENERATOR	18
SOLAR PANELS	19
WIND TURBINE	19
POWER SYSTEM PERFORMANCE TEST	19
MAINTENANCE	20
CONCLUSION	20
ACKNOWLEDGEMENTS	21
REFERENCES	21

ABSTRACT

Enzenhofer, H.J., Cronkite, G.M.W., Holmes, J.A., and Lilja, J. 2007. Power supply system for remote site application. Can. Tech. Rep. Fish. Aquat. Sci. 2730: v + 21 p.

Operating electronic equipment in remote locations requires a dependable source of electricity for sustained periods. In this report we describe the design, construction, assembly and deployment of a power supply system for use in sites remote from electrical utility lines. The system has a modular design consisting of a combination of solar panels, water generator and wind turbine to generate DC electricity and store it in a battery bank comprised of four high storage capacity 6 V batteries. The stored power is converted on-demand from 12 VDC to 120 VAC by a 1500 watt DC-AC pure sine wave inverter. Site selection is important for effective electricity generation using alternate sources. Not all sites will be optimal for each generation method, but based on our experience solar panels and usually one other alternative will be effective at most field sites. Thus, a site needs to be unobstructed by overhanging tree canopy and there must be a level area for anchoring the base of the combined solar panel stand and wind turbine mast. The results of a continuous load test using a 150 Watt lamp show that the battery bank (using the batteries specified) dropped to 40-50% charge after 3 days when there was heavy cloud cover, no wind and the water generator was producing a steady input of 1.7 Amps. At this level of depletion, a 40 Amp external charge for 10 hours would be required to restore the battery bank to 100% charge. The battery bank can be deployed as a stand-alone power source using a stand-by generator and charger for periodic recharging. Current costs to construct the weatherproof and lockable power-pac, including the battery bank and electrical equipment needed to regulate charging, output from the generators and conversion from DC to AC current, was \$8,900 CAN. Cost to build and equip the telescopic solar panel stand with solar panels, the 400 Watt wind turbine and mast, and the 100 Watt water generator with guard, mounting pole and tripod, were approximately \$5,700, \$1,700, and \$3,500 CAN, respectively.

RÉSUMÉ

Enzenhofer, H.J., Cronkite, G.M.W., Holmes, J.A. et Lilja, J. 2007. Power supply system for remote site application (système d'alimentation pour application d'emplacement éloigné). Rapp. tech. can. sci. halieut. aquat. 2730: v + 21 p.

Le fonctionnement du matériel électronique à des emplacements éloignés exige une source fiable d'électricité durant des périodes prolongées. Le présent rapport décrit la conception, la construction, l'assemblage et la mise en service d'un système d'alimentation destiné à des emplacements éloignés des lignes utilisées par les services publics d'électricité. De conception modulaire, le système combine des panneaux solaires, une génératrice hydroélectrique et une éolienne pour produire de l'énergie c.c. et l'emmagasiner dans un banc de batteries comprenant quatre batteries de 6 V à forte capacité de stockage. L'énergie emmagasinée est convertie sur demande de 12 V c.c. à 120 V c.a. par un onduleur c.c.-c.a. de 1 500 watts à onde sinusoïdale pure. Le choix de l'emplacement est important pour la production efficace d'électricité au moyen de sources d'énergie nouvelle. Certains emplacements ne se prêtent pas bien à chaque méthode de production, mais l'expérience a démontré que les panneaux solaires et habituellement une autre source d'énergie nouvelle conviennent à la plupart des emplacements. Ainsi, un emplacement doit être dégagé de tout couvert forestier et comporter une zone plane permettant d'ancrer la base du support de panneau solaire et le mât d'éolienne combinés. Les résultats d'un essai en charge continue, effectué à l'aide d'une lampe de 150 watts, indiquent que le banc de batteries (utilisant les batteries spécifiées) a chuté à une charge de 40-50 % après 3 jours sous une épaisse couverture nuageuse, en l'absence de vent et alors que la génératrice hydroélectrique produisait un courant stable de 1,7 A. À ce niveau d'appauvrissement, une charge externe de 40 A durant 10 heures serait nécessaire pour ramener le banc de batteries à une charge de 100 %. Le banc de batteries peut servir de source d'alimentation autonome utilisant une génératrice de secours et un chargeur pour effectuer une recharge périodique. Les coûts actuels de construction du bâti d'alimentation étanche et verrouillable, contenant le banc de batteries et le matériel électrique nécessaire à la stabilisation de la charge, à la sortie des génératrices et à la conversion du courant c.c. en courant c.a., était de 8 900 \$ CAN. Les coûts requis pour fabriquer le support télescopique et l'équiper de panneaux solaires, les coûts de l'éolienne de 400 watts et du mât et les coûts de la génératrice hydroélectrique de 100 watts avec protecteur, poteau de montage et trépied s'élevaient respectivement à environ 5 700 \$, 1 700 \$ et 3 500 \$ CAN.



INTRODUCTION

Operating electronic equipment or appliances in remote locations usually requires the use of portable generators to supply electrical power. Providing a constant flow of fuel for these generators can be an onerous task if the remote site is being operated on a 24 hour basis. The impact of continuous noise during the running of the generator, and regular maintenance requirements makes the use of other power sources a favourable alternative.

We developed a power supply system that utilizes solar panels, a water generator and a wind turbine to charge a battery bank. The battery bank stores the generated power and on-demand converts it from 12 VDC to 120 VAC through an inverter to power equipment. Although the use of solar, wind and water is not a new concept, there is no practical package available commercially that provides all the required components for remote site operation. If resources are insufficient to permit the inclusion of solar, wind or water power generation units, then the power-pac can be operated on battery power alone using a standby generator and charger to recharge the battery bank periodically. Individual power source components can be added at any time through pre-wired cable connection points. Once assembled and deployed, the power-pac has the required charge controllers and electrical components to be a functional plug-and-play electrical source.

The objectives of this report are to describe the design, construction and function of individual components of the power supply system, including wiring diagrams, and provide instructions on component assembly and deployment on-site. We also test the performance of the system using a constant demand of a 150W lamp in various climatic conditions (sun, cloud, foul weather) to determine if alternate battery charging (i.e., a portable generator) was required. Costs to construct the system components and purchase the power generating equipment are provided in 2007 Canadian dollars. Lastly, because site selection is important for the effective operation of the power supply system, we discuss recommendations for maximizing the outputs from the solar, wind and water generators.

DESCRIPTION

The function of the power supply system is to store the energy produced by alternate power sources in a battery bank and supply that energy through an inverter to operate equipment requiring AC electrical current. The power supply system has four primary components: 1) a power-pac with high storage capacity batteries, a 12 VDC -115 VAC power inverter, a battery monitor, charge controllers, breakers and associated electrical components; 2) a telescopic solar panel stand with horizontal and vertical adjustment to optimize the angle of the solar panels relative to the incident angle of the sun; 3) a wind turbine with a

mounting mast that can be affixed to the solar panel stand and; 4) a submersible hydro generator (Ampair 2007) with a mounting tripod for stream, creek or river application (Fig. 1).

Equipment produced by various manufacturers was selected for use in the power system described in this report. Substituting different products may change power system performance in terms of the specified inputs and/or outputs. Mention of manufacturers names and product models does not imply endorsement of the manufacturer or product by Fisheries and Oceans Canada or the Government of Canada.

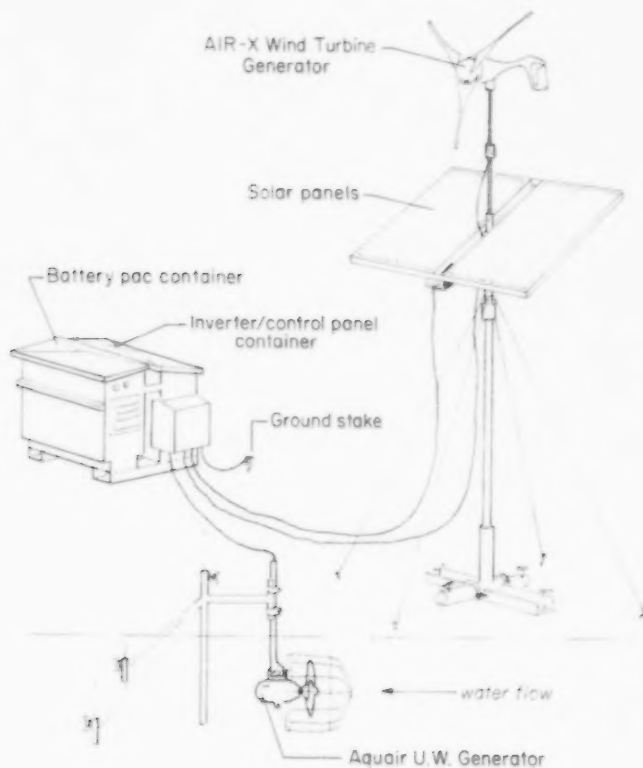


Fig. 1. Three-dimensional view of the power supply system for a remote site utilizing wind, solar and water energy to charge a battery bank for power storage.

POWER-PAC

The power-pac has two connected and ventilated compartments constructed of welded 14 gauge stainless steel (SS) mounted on two SS channels (Fig. 2). One compartment houses four 6 V batteries (Trojan L16HC), a 12 V power shutoff switch and remote jumper terminals (MOROSO) that provide access to 12 V power and allow charging with an external battery charger. The other compartment houses a 12 V input pure sine wave inverter (GO Power GP-SW1500), a battery monitor (Xantrex Link 10), a solar charge controller (Solar Boost SB2000E), a water generator charge controller (Ampair model S-1B-12), output terminals for 12 VDC power, a surge protected power bar for 120 VAC power, circuit breakers and all cable connections for input of alternate power sources (Fig. 3, Photo 1).

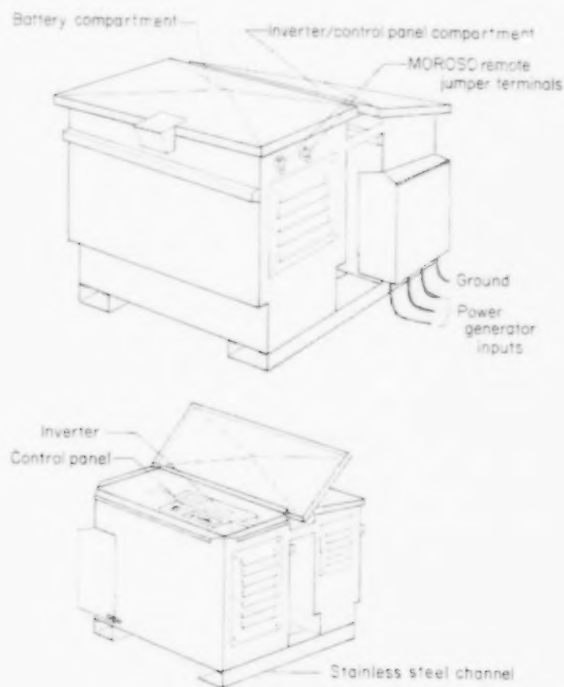


Fig. 2. Three-dimensional view of the power-pac showing the stainless steel compartments which house the battery bank and the electronic components for the power supply system. Both compartments are connected and sit on two stainless steel channels used for lifting and transporting the system.

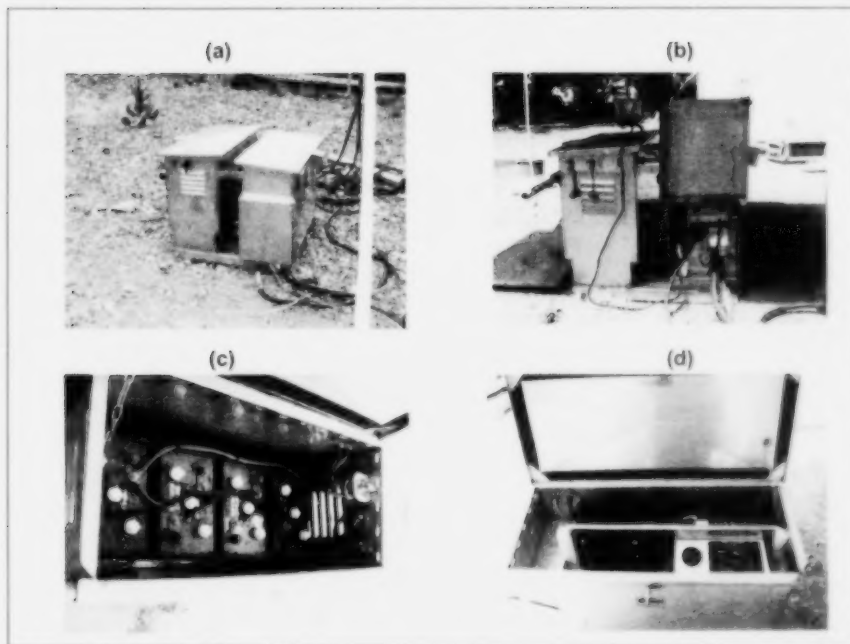


Photo 1. Two compartment power-pac for a power supply system. (a) louvered battery compartment and the control panel compartment with hinged access lids (b) cable access points for input of the solar panels, wind turbine and water generator (c) batteries with a 12 V shutoff switch and; (d) control panel with inverter mounted to a removable sliding tray. Both compartments are ventilated and contain weather stripping for protection from the elements.

Design

The power-pac is designed to accept incoming electrical power from wind, water or solar sources or a combination of these sources. The system can also be deployed as a stand-alone battery power supply system, using a portable generator and charger periodically to maintain its charge. The power-pac is designed to be weatherproof and each compartment has latches for secure locking. The overall container dimensions are 78 cm high x 111cm wide x 96 cm long and it weighs approximately 255 kg (Fig. 3) when fully configured.

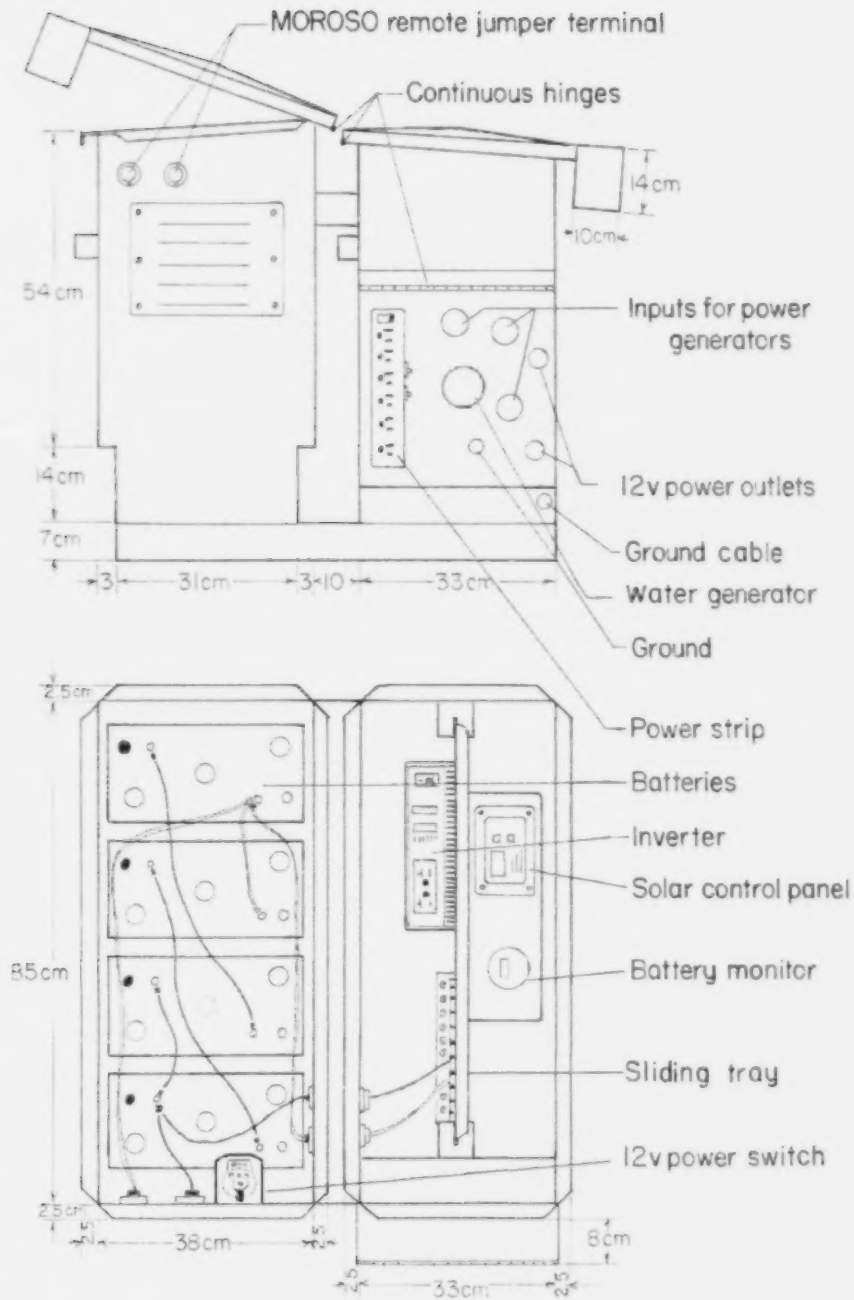


Fig. 3. Schematic of the power-pac showing overall dimensions and major components. The top diagram is a side view of the cable access points. The bottom diagram is a top view of the battery and control panel compartments.

Wiring details

The complete power supply system has the potential to generate a current of approximately 54 Amps per hour using the specified solar panels, wind turbine and water generator connected simultaneously and producing electrical power at their maximum rated outputs (Fig. 4).

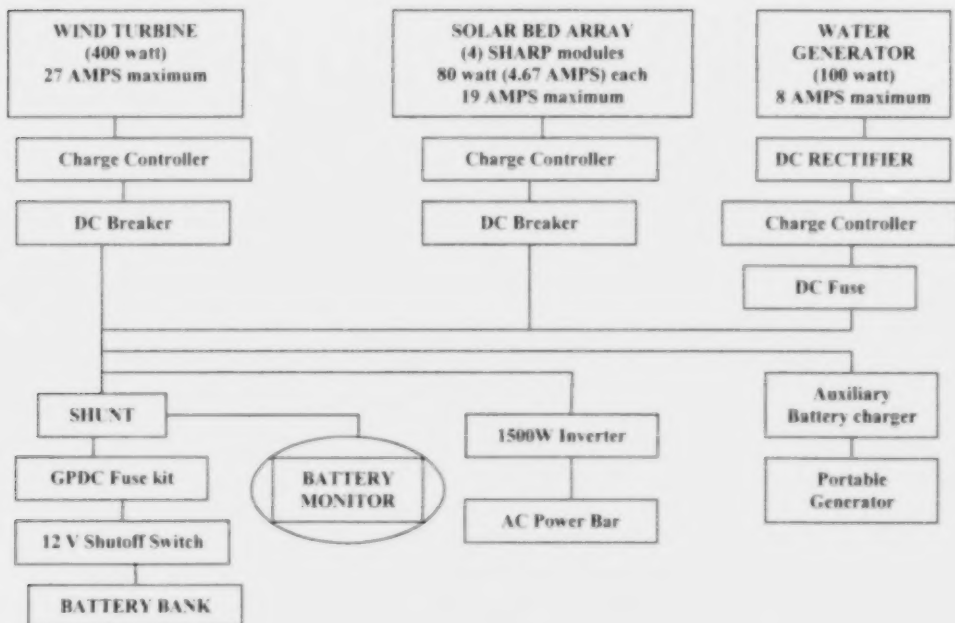


Fig. 4. Schematic showing the basic components for the Power Supply System

Battery compartment

The battery compartment contains four 6 V Trojan L16HC marine batteries (420 Amps at 20 hr AH rating) that are connected in series and parallel, resulting in an electrical storage capacity of 840 Amps (20 hr AH rate) at 12 VDC (Fig.5). The 6 V batteries were chosen because of their high storage capacity, durability and reliability in renewable energy systems even in harsh environments.

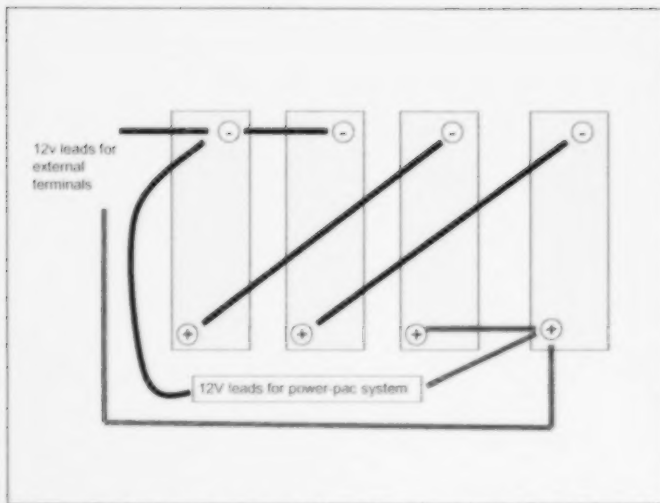


Fig. 5. Schematic showing four 6 VDC batteries connected in series and parallel to produce two banks of 12 VDC power.

Control panel compartment

The control panel compartment has all necessary wiring and electrical components to control charge to the battery bank, accept electricity from the alternate power sources and to distribute AC electricity to appliances. A spare 50 Amp plug is also provided so that an additional wind turbine or water generator can be added to the system. Unlike the solar panels and water generator, the wind turbine that we used is internally controlled and can be plugged directly into the power-pac without the need for an external charge controller. However, if a second water generator is added through the empty auxiliary plug, then both a DC rectifier and charge controller would be required. A complete wiring schematic of the power-pac is shown below (Fig. 6).

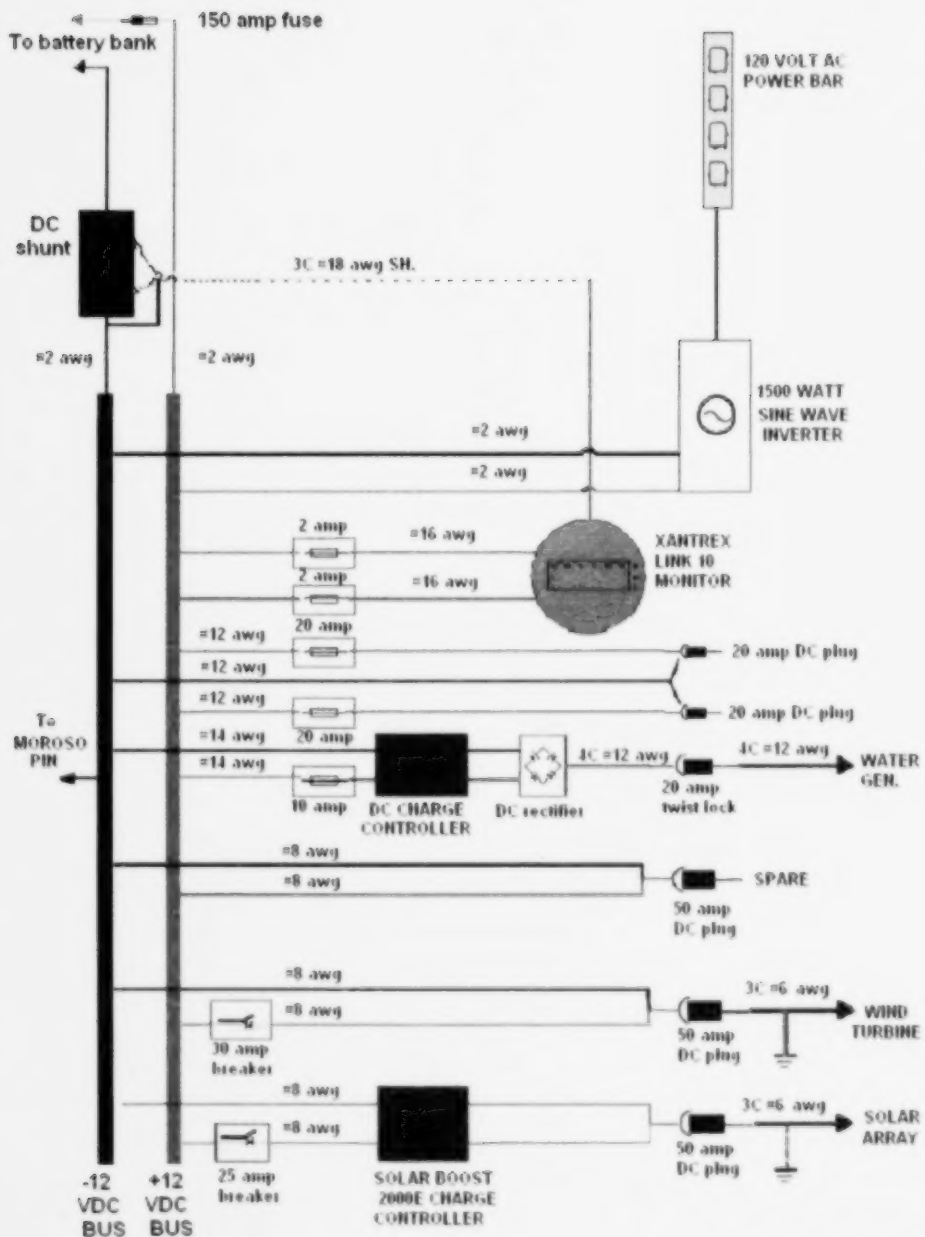


Fig. 6. Wiring details and components in the control panel compartment of the power-pac for a Power Supply System. Wire sized using the American Wire Gauge (AWG) system in which a higher gauge number indicates smaller wire diameter.

TELESCOPIC SOLAR PANEL AND WIND TURBINE STAND

The telescopic solar panel stand is an aluminium structure that is extendable to a height of 4 m. The stand is designed to mount four solar panels in a frame, which creates a solar bed array that can be rotated 360° horizontally and 45° vertically in 5° increments to optimize the array angle to incident sunlight. The telescopic main pole has a receiver at the top for mounting a 3 m mast to attach a wind turbine. Once the solar panel stand has been fully assembled on the ground, it can be safely raised and secured into operating position by three people. Raising the stand is similar to raising a flagpole in that the stand is rotated to an upright position while attached to a base yoke secured to a base channel by two U-bolts (Fig. 7).

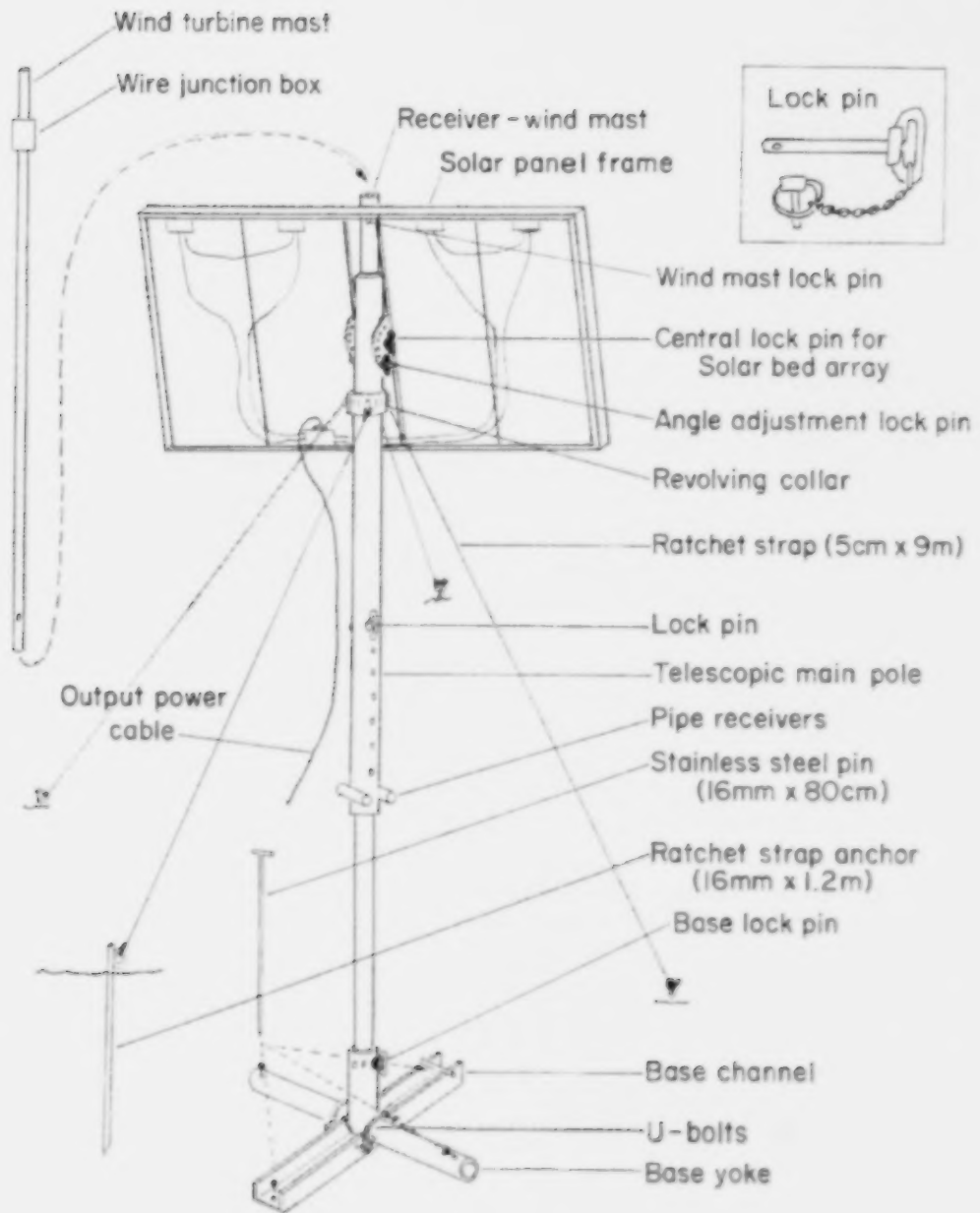


Fig. 7. Three-dimensional view of the solar panel stand. The top right enlarged diagram shows the lock pins used throughout the assembly of the telescopic stand.

Construction

The telescopic solar panel stand has three main components: 1) a stand base; 2) a telescopic main pole; and 3) a solar panel frame (Fig. 7).

The stand base consists of one piece of aluminium channel (5 cm x 15.5 cm x 113 cm) that is coped in the center and has bolting flanges welded to the top to accept two U-bolts which attach the base yoke to the base channel. The base yoke is constructed of aluminium pipe (10 cm OD x 122 cm) and has a main pole receiver pipe (10 cm OD x 30 cm) centrally welded upright at a 90° angle. The main pole receiver has 16 mm holes drilled around the top of its circumference for a lock pin, securing the main pole to the stand base. Both the base channel and base yoke have 16 mm holes drilled at their ends through which stainless steel pins are inserted to anchor the entire assembly to the ground (Fig. 7).

The telescopic main pole is an aluminium pipe (schedule-80, 9 cm OD x 213.5 cm) that attaches to the main pole receiver and travels inside a larger aluminium pipe (schedule-40, 10 cm OD x 274 cm), creating a two piece extendable pole. The bottom 90 cm of the larger pipe has 16 mm holes drilled at 15 cm spacing to receive a lock pin that connects the two pipe sections. Two pipe receivers (2.54 cm ID x 15 cm each) are welded to the larger pipe and are used to adjust the horizontal position of the solar panel array with a 2.54 cm OD pipe. The wind turbine mast receiver (5 cm ID x 42 cm aluminium pipe) is welded to the top of the telescopic main pole for attaching the wind turbine mast (5 cm OD x 3 m length). Finally, a revolving collar (10 cm ID), with four loops to attach ratchet straps to secure and support the stand, is held in place at the top of the main pole by a pipe (10 cm OD) welded to the main pole underneath the collar. The telescopic stand should never be used without the ratchet straps as they provide integral support for the structure.

The solar panel frame is constructed of 7.6 cm x 5 cm x 3 mm thickness aluminium angle welded to form a frame 121 cm x 226.5 cm to fit four solar panels (54 cm x 120 cm each). Two aluminium angle pieces (10 cm x 8.0 cm x 121 cm at 6 mm thickness) are welded to the center of the solar panel frame with a 10 cm opening between them and two semi-circular plates with 16 mm angle adjustment holes (28 cm x 18 cm x 6 mm thickness) are centrally welded to these pieces. The telescopic main pole passes through the central opening in the frame and is connected to the solar panel frame by lock pins inserted through the aligning holes of the two semi-circular plates.

Assembly instructions

A suitable site should be selected to assemble the solar panel stand. The site should be level and free of large trees in the immediate area and it should allow unimpeded access to sun and wind energy (Photo 2). It is equally important to use level ground when positioning the stand. The stand can be mounted to a sloped bank but the base itself should be level.

Important! Safety is a major consideration and attempts to fully assemble the telescopic stand should only be done on a calm day!

Assembly is in the following order:

1. Secure the base channel portion of the stand base using the two 1m SS stakes;
2. Insert the base yoke onto the grooved center portion of the channel base and install the two U-bolts. Tighten to the point where the stand base is secure but still allows the yoke to be swung upright;
3. Insert the bottom pipe of the telescopic main pole into the yoke and insert the base lock pin through an aligning set of holes;
4. Extend the telescopic pole to the desired height by removing the lockable pin that joins the two pipe sections, set desired length and then reinstall the lock pin;
5. Install the solar bed array to the telescopic main pole first with the central lock pin and secondly with the vertical adjustment lock pin (Fig. 7);
6. If using the wind turbine, then install the 3 m mast into the mast receiver on the top end of the stand using the lockable pin;
7. Install the wind turbine;
8. Install the four galvanized ratchet strap anchors at the four diagonal corners approximately 5 m from the stand base. The 5 m distance is a minimally acceptable distance for anchoring the stand. Longer distances provide more lateral support while shorter distances are not recommended;
9. Attach the four ratchet straps to the revolving collar mounted on the top end of the telescopic main pole;
10. Using two people on the stand and one on a ratchet strap pivot the stand to it's vertical position;
11. Attach all four ratchet straps to their galvanized pegs, equalize tension and ensure that the stand is vertical. Note that steps 8-11 are critical safety steps and must be followed; and
12. Secure the pipe yoke with two SS pins and fully tighten the two U-bolts on the stand base.



Photo 2. Solar panel stand with attached mast and wind turbine showing an ideal location with level ground free of large trees in the immediate area.

Adjustment of the solar panel bed

The solar panel bed can be rotated 360° horizontally and 45° vertically in 5° increments in order to optimize the angle of the array to incident sunlight. These adjustments can be made safely and quickly once the solar panel stand has been fully installed and will not affect the position of an installed wind turbine and mast.

- Horizontal adjustments are made by removing the **base lock pin** connecting the telescopic main pole to the base yoke, inserting a length of pipe (2.54 cm OD) into the pipe receivers, turning to the desired position and re-inserting the lock pin (Fig. 7). The ratchet straps remain intact because they are attached to a revolving collar that allows the main pole to rotate inside the base yoke.
- Vertical adjustments are made by removing the **angle adjustment lock pin** and setting the desired angle for the solar bed array (Fig 7).

WATER GENERATOR

We use an Ampair UW submersible hydro generator with a maximum output of 8.3 Amps at 12 Volts DC, 200 Amp-Hours (AH) per day (2.4kW) at a current velocity of 4 m/s. This unit will produce 1.5 kW per day in a current velocity of 2.6 m/s. The 31.8 cm diameter standard propeller requires a minimum of 33 cm of water depth for operation, and is covered with a bolt-on propeller guard for protection against debris. The generator comes with a 1.0 – 1.5 m long mounting pole (5.0 cm diameter), which bolts onto the generator and is affixed to a tripod placed in the stream. We designed a simple tripod constructed of galvanized pipe that is anchored to the stream bottom with three stainless steel anchor pins (Fig.8).

The tripod is constructed of one vertical pipe (3.5 cm OD x 92 cm) that has two diagonal legs (3 cm OD x 92 cm) welded at a 45° angle to the vertical pipe (70 cm spacing between each leg at their base). Each diagonal leg has a pin holder (3 cm OD x 15 cm) welded at 45° angle and a lock nut at the top for securing a stainless steel anchoring pin (16 mm diameter x 1.5 m) perpendicular to the bottom surface. The larger vertical pipe has a lock nut at the top for securing a stainless steel pin (20 mm diameter x 1.5 m) that provides additional support against water currents. An arm for attaching the mounting pole of the water generator is welded at 90° to the vertical pipe (Fig. 8).

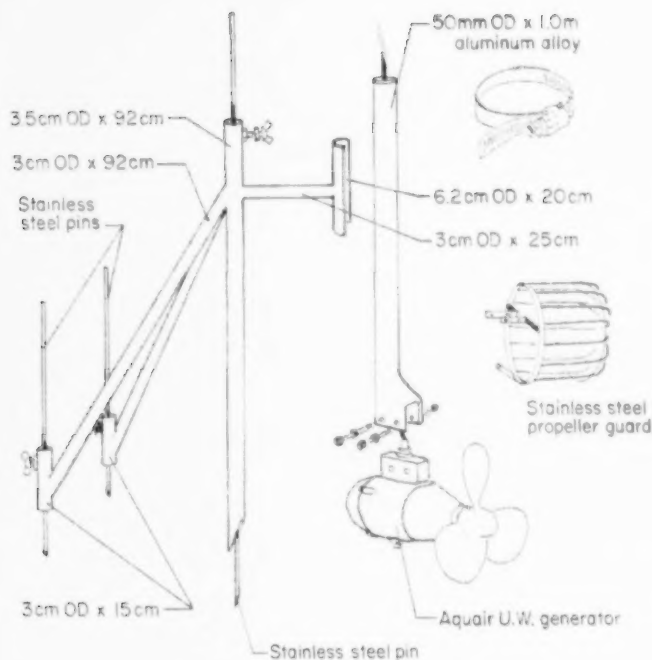


Fig. 8. Three-dimensional view of the Aquair U.W. (Ampair) water generator, the mounting pole and stand for installation in flowing rivers or streams. Diagram on left shows the tripod stand with anchor pins that are driven into the bottom substrate. The center figure shows the mounting pole which bolts to the generator and is affixed to the tripod using pipe clamps shown on the top right. A stainless steel guard (bottom right) keeps debris away from the propeller and reduces the potential for contact by humans, fish and other aquatic animals.

Assembly

The tripod is used to deploy the water generator on an uneven river bottom by adjusting the position of three SS anchor pins inserted inside the tripod legs (Fig.8). Each anchor pin is driven into the substrate and locked with a wing nut to achieve a stable platform and alignment of the mounting pole attachment bracket perpendicular to the water surface. The bolting flange of the mounting pole is fixed to the submersible generator and attached to the mounting pole attachment bracket with two SS pipe clamps.

WIND TURBINE

We used an AIR-X wind turbine (Southwest Windpower 2002) capable of producing 400 Watts of power (27 Amps) at a wind speed of 12.5 m/s. This turbine has internal electronics which incorporate voltage regulation, peak power tracking and stall control in high winds. The turbine has a rotor diameter of 1.17 m and weighs 6 kg. The base of the turbine (Yaw clamp) will fit a 5 cm diameter pipe and can be attached directly to the wind turbine mast.

The wind turbine mast is a 3 m length of galvanized pipe (5 cm OD) with a weatherproof wiring junction box that allows the leads from the turbine to be connected inside the mast pipe. A single cable (3C #6 AWG-600V) with 2-pole connectors leads out of the junction box and plugs directly into the power-pac (Fig. 3). The bottom of the wind turbine mast has a 13 mm hole to connect the wind turbine mast to the telescopic main stand using a lock pin (Fig. 7).

GROUNDING

The power supply system is grounded to earth at several points for safety. The power-pac unit is grounded via a 2 GA-600V welding cable clamped to a grounding rod and each of the alternate power sources are grounded via the power-pac (Fig. 1, 3 and 6). Electronic components within the power-pac are equipped with breakers and a 150 Amp ground protected DC fuse kit. We also used a surge protected power bar to operate electronic equipment from the DC-AC inverter. The solar panels are grounded to the solar panel frame and the telescopic stand is grounded at the base of the stand.

COSTS

The approximate costs, including labour and materials, to construct the power supply system are shown in Table 1. We show the four major components as separate items as they can be added to the power-pac at any time. All figures are in 2007 Canadian dollars.

Table 1. Approximate cost for a power supply system.

Item	Description	Cost
Power-pac (stainless steel construction)	<u>Battery compartment</u> • (4) 6 V Trojan L16HC marine batteries • MOROSO 12 V kill switch • MOROSO remote jumper terminals <u>Control panel compartment</u> • Solar Boost 2000E charge controller • Ampair S-M1B charge controller • XANTREX Link 10 battery monitor (with Shunt) • GP-SW 1500 Watt Inverter • GPDC fuse kit (150 amp) • (2) 20 amp 12 VDC plugs • Wired plugs for input of solar, wind and water power • Auxiliary power source input plug (50 amp) • Complete wiring (with breakers and fuses) • Ground cable and ground stake • AC power bar	\$8,900
Telescopic Solar Panel Stand (aluminium construction)	Solar bed (360° horizontal and $\pm 45^\circ$ vertical adjustment) • (4) Sharp 80 Watt panels • Receiver for adding wind turbine mast • (4) 5 cm x 9 m ratchet straps • (4) ratchet strap anchors (16 mm x 1.2 m) • (4) SS pins (16 mm x 80 cm) • Wired and c/w 15 m cable (3/C #6 AWG-600V)	\$5,700
AMPAIR UW 100 hydro generator	100 Watt (8.3 Amps) maximum output • Standard propeller • Stainless steel guard • Mounting pole (1.5 m length) • DC rectifier • Wired and c/w 33 m cable (4/C #12 AWG) • Tripod stand c/w SS pins	\$3,500
AIR X Wind turbine	400 Watt (27 Amps) maximum output • Internal charge controller • Wired and c/w 15 m cable (3/C #6 AWG-600V) • 3 m mounting mast	\$1,700

DISCUSSION

We assessed the performance of the power supply system at the Department of Fisheries and Oceans salmon research laboratory at Cultus Lake, BC, from April 24 to May 18, 2007. The water generator was installed in Sweltzer Creek, which had a measured current velocity of 1.44 m/s and water depth of 0.7 m at our test site. The solar panel stand with attached wind turbine was assembled and deployed beside the creek approximately 10 m from the bank edge. The selected site had a large canopy opening directly overhead, but also had several large conifers nearby that partially blocked sunlight during the early morning hours.

WATER GENERATOR

With an average measured current flow of 1.4 m/s through our test site, the Aquair UW generator produced 1.7 Amps continuously as detected by the Xantrex Link 10 battery monitor in the power-pac. This output was consistent with the performance graph given by the manufacturer using the standard propeller on our unit. The manufacturers' performance graph indicated the following outputs (Ampair 2007):

Flow rate (m/s)	Amps at 12 V
1.0	<0.5
1.5	2.2
2.0	4
3.0	6+
4.0	8.3 (maximum)

Installing the water generator at a site with current velocities of 2.0 m/s or greater would more than double the power production to 4 Amps. At flow rates of 1.5 – 2.0 m/s the water generator should produce sufficient output on its own to support an acoustic system such as a DIDSON imaging sonar whose power consumption is rated at 30 Watts.

The water generator was a reliable and constant 24 hr source of electricity, although production was limited in our testing by the lower current velocity. Realistically, attempts to wade in current velocities greater than 2.0 m/s to install the tripod and the water generator would be difficult. Alternate approaches for installation should be considered such as building a simple water concentrating channel to increase flow velocity and channel the water towards the generator. Other mounts could be devised to allow the generator to be mounted to stable in-river structures such as weirs or bridge abutments in higher flow areas.

SOLAR PANELS

The four 80 W solar panels used in our system had the ability to produce a combined output of 19 Amps in direct sunlight. We were able to attain this maximum output during periods of peak sunlight, but over the entire test period the solar array averaged 4 Amps/ hr over a 24 hr period since our test involved periods of cloud cover not uncommon for early springtime. The average output should increase as the hours of sunlight increase and in areas less affected by tree canopy (see Photo 2). Thus, for optimal solar panel operation a site with tree canopy openings that are sufficiently large so that trees do not intercept sunlight during the early morning and late afternoon periods are preferable.

WIND TURBINE

Maximum output from this wind turbine is 400 Watts or 27 Amps, which is the highest output of the three sources tested. We found that electricity generation with the wind turbine is more dependent on proper site selection than the solar panels or water generator. Our test location was mostly protected from wind and so we seldom received power from the unit. Sites with very large canopy openings or sites in which the wind turbine can be raised above the canopy will be most efficient for wind generation. The manufacturers' performance specifications indicated the following outputs (Southwest Windpower 2002):

Wind speed	Power output (Watts)
7 mph (3.0 m/s)	20
15 mph	50
18 mph	100
24 mph	200
28 mph (12.5 m/s)	400 (maximum)

POWER SYSTEM PERFORMANCE TEST

We used a 150 Watt lamp to simulate the power consumption of a typical fixed-location hydroacoustic site which might include the following equipment:

- DIDSON imaging sonar (30 Watts), or
- Digital Split-beam hydroacoustic system (30 Watts), and
- Laptop computer (40-80 Watts).

The test load represented a draw of 14 Amps which was observed on the battery monitor (Xantrex International 2002). The user can quickly determine the draw of appliances or contribution of the individual power sources by unplugging individual components or adding appliances and measuring the amperage differences. The monitor has the following displays:

- **VOLTS** to assess the approximate state of charge of the battery bank. Volts represent the electrical potential to do work.
- **AMPS** are the present flow of current in or out of the battery bank. The 150 Watt lamp would be displayed as -14 Amps if there was no input from the charging devices.
- **AMP HOURS** represents the amount of energy removed from the battery bank. The battery size must be programmed into the battery monitor as it comes with a factory default setting for a 200 Amp hr battery size.
- **TIME** which is an estimate of the amount of hours the battery bank will sustain the load.

Our battery bank uses four 6 V batteries 420 Amp hrs (20 hr rate) giving a total of 840 Amp hrs at 12 V. The battery monitor has a light bar display which shows state of charge at a glance using a series of green, yellow and red LED lights which range from four green representing a full battery (80-99%) and a flashing red light indicating a charge status of 0-19%. A battery is usually considered 100% discharged when voltage output drops below 10.5 V, but lead acid batteries usually should be recharged at 50% discharge (two yellow bars on the battery monitor) for best performance. Depleting the battery bank below 50% discharge occasionally will not harm the batteries, however, the DC-AC sine wave inverter requires a minimum input of 11 V for proper operation. Lower voltages will cause the inverter to shutdown automatically, cutting off the AC electrical supply. At the end of our 3 day test period using the 14 Amp draw, the battery monitor indicated a 40-50% charge status (two yellow bars). At this stage we would consider using an external battery charger to bring the batteries up to full charge (example 40 amp charge for a 10 hr period).

MAINTENANCE

Maintenance of the power supply system is minimal. Users should check for cracks in pipes and welds at the beginning of the field season and all electrical connections and cables should be checked as well. Proper battery care should be followed throughout their use, including periodic checking and maintenance of fluid levels using distilled water. Batteries should never be stored in an uncharged state in sub-zero weather and periodically the charge should be equalized (e.g., monthly or every 10 discharges) by using the equalize function on the solar charge controller (Blue Sky Energy 2004).

CONCLUSION

The power supply system is a dependable source of electricity for the operation of electronic appliances for sustained periods. One advantage of this system is that it supplies clean 120 VAC power, which is important for the continuous operation of electronic equipment that may be sensitive to voltage

fluctuations. Our test involved a continuous current load to the battery bank and would eventually deplete available power if there were sustained periods of minimal input power. Effective operation of the power supply system depends on proper site selection and the principal selection criterion is a large canopy opening that does not restrict wind or light when the sun is low to the horizon. If the site has sufficient sun, wind and water power, then the battery bank can supply continuous power to operate a heavy current load. However, often the site will not be optimal for all power sources and may require periodic input from an external battery charger.

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REFERENCES

- Ampair, 2007. UNDERWATER 100 (UW 100) Operation Installation & Maintenance Manual. Park Farm, Warfield, Berkshire, UK
- Blue Sky Energy, Inc. 2004. SOLAR BOOST 2000E Installation and Operation Manual. Blue Sky Energy, Inc., Vista, California.
- Southwest Windpower, Inc. 2002. Air-X Owner's Land Manual. Document #0056 REV D. Southwest Windpower, Inc., Flagstaff, Arizona.
- Xantrex International. 2002. Xantrex Link 10 Battery Monitor: Owner's Manual. November 2002, Revision 1, Xantrex Technology Inc.

